Independent measurement of high blood pressure changes in cuff-less blood pressure monitoring

Conclusions: Moderate/severe acute allograft rejection is associated with ECG changes following transplant surgery. Future studies are needed to assess the value of computerized ECG measurement algorithms for detecting acute allograph rejection.

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Independent measurement of high blood pressure changes in cuff-less blood pressure monitoring

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Hypertension is the main cause of deaths in 55.3% of cardiovascular patients globally and 30% of our population over the age of 40 is a victim of this silent killer. Arterial stiffness (AS) is the main cause of hypertension and pulse wave velocity (PWV) is the current measurement gold standard for AS. Pulse arrival time (PAT), the measure of PWV, has shown to demonstrate a strong correlation with blood pressure measurement.

Moen-Korteweg measured fluid propagation velocity in the elastic tube equation. Hughes investigated the arterial elasticity modulus which showed exponential relationship of blood pressure (BP) and the correcting factor equation thus leading to the Eq. (1) which describes the relationship between blood pressure and PAT as:

$$P = \frac{1}{\alpha}\ ln\left(2r\rho\frac{\Delta X^2}{E_o h}\right) - \frac{2}{\alpha}\ ln\left(tt_{pat}\right) \quad (1)$$

Where P = Pressure; r = Artery inner radius, ΔX = Distance between heart and index finger, E_o = Young's Modulus, h = Artery wall thickness, ρ = Blood density tt_{pat} = PAT & α = alpha.

When BP changes from normotensive to stage II hypertension condition, it produces very small changes in PAT values (0.30 to 0.50 s) which intrinsically displays limited logarithmic behaviour compared to normalized range. This work has formulated an important log relation of the Hughes correcting factor (alpha) and the PAT value, with numerical range estimation and logarithm transformations. This enables one to predict abrupt high blood pressure (rises greater than SBP = 60 mm Hg & DBP = 40 mm Hg). First, we have normalized the PAT and alpha components followed by an application of the log transformations. We then rescaled back to the original values range. This was followed by a one-to-one assignment of the parameters (alpha and PAT).

PWV increases over the person's age and depends on several factors like gender, ethnicity and lifestyle. Keeping these factors under consideration, we have used a publically available MIMIC II (Multiparameter Intelligent Monitoring in Intensive Care) data set and have selected 10 male patients of age 75 ± 4(SD) years, with blood pressure: SBP 120 + 80 mm Hg and DBP 80 + 50 mmHg. We have calculated the PAT by measuring time-difference between electrocardiogram (ECG) R-peak (detected by Pan Tompkins method) and the first derivative of the peak of photoplethsmogram (PPG). We have estimated systolic BP (SBP) and diastolic BP (DBP) individually from PAT. Finally, Bland-Altman agreement analyses has shown a good compliance of SBP estimation (±28 SD) compared to DBP estimation in relation to PAT.

In conclusion, the novel relationship between alpha and PAT is able to estimate abrupt high changes in BP. Furthermore, PAT trends have shown stronger relationship to SBP compared to DBP.

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Bipolar chest leads revisited: The optimal placement of patch based ECG devices

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Before multi-lead electrocardiogram (ECG) systems were readily available a significant amount of research was performed into the optimal placement of bipolar ECG electrodes for ambulatory and exercise ECG monitoring. However, bipolar chest leads (BCLs) are used rarely nowadays. In recent years, a number of patch based ECG devices have emerged focused on continuous rhythm monitoring. ECG patches typically record a single BCL but are constrained by small inter-electrode distances making some ECG features, such as P-waves, difficult to detect. In this study we aim to determine new BCLs at a range of small inter-electrode distances for maximum P-wave and QRS amplitude, providing optimal patch locations for long-term ECG rhythm monitoring.

The study data consisted of 120-lead BSPMs recorded from 744 patients (229 healthy, 278 MI, 237 LVH). The dataset was then randomly split into a training dataset of 560 patients and a testing dataset of the remaining 184 patients. To improve spatial resolution, the 120-lead were expanded to 352 nodes which correspond to the nodes of the Dalhousie torso. An exhaustive lead selection method was applied to each map from which 61,776 unique bipolar ECG leads were established for each patient. Inter-electrode distances for each lead was then calculated from the Euclidean distance between nodes on the Dalhousie torso model. Maximum P-wave and QRS amplitudes were calculated from each lead and median values taken across the training population. New BCLs were then determined at inter-electrode distances of 1, 2, 3 and 4 in. and compared to the Mason-Likar (ML) Limb leads and the current standard ECG patch location (below the left sternoclavicular joint towards the left nipple).

There was a strong linear relationship between inter-electrode distance and median ECG amplitude achieved for both the P-wave (R = 0.98) and QRS complex (R = 0.93). Generally, the best performing BCLs for P-wave amplitude were located on or just above precordial leads V1 and V2. For the QRS complex, electrodes placed horizontally between the third and fourth left intercostal space provided the greatest QRS amplitude.

This study provides a definition of the optimal placement of bipolar ECG patches for P-wave and QRS-complex signal amplitude, at specific inter-electrode distances. The demonstrated improvement in signal magnitude may lead to more accurate rhythm monitoring using ECG patches by reducing the amount of false positive alarms due to high signal-noise.

Table 1. ECG amplitudes from new bipolar chest leads compared to the Mason-Likar Limb Leads and the currently used ECG patch location.

Lead	P-wave amplitude (μV)	QRS amplitude (μV)
Current Patch Placement	16 [0–41]	458 [20–1206]
BCL_{P1}	30 [2–92]	180 [8–675]
BCL_{P2}	55 [0–124]	145 [0–1005]
BCL_{P3}	89 [9–167]	413 [8–1619]
BCL_{P4}	105 [9–188]	467 [9–1692]
BCL_{QRS1}	14 [0–41]	621 [68–1629]
BCL_{QRS2}	27 [4–68]	1006 [100–3254]
BCL_{QRS3}	36 [10–96]	1576 [265–4601]
BCL_{QRS4}	42 [10–107]	1784 [265–4602]
ML I	17 [0–61]	172 [35–712]
ML II	128 [22–216]	982 [107–2718]
ML III	52 [2–134]	485 [7–816]

Values represent median and [96% range].

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